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NEW RADIOACTIVE ISOTOPES OF IRIDIUM

By
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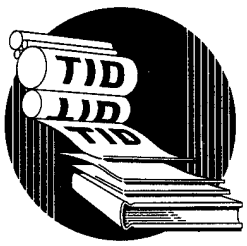

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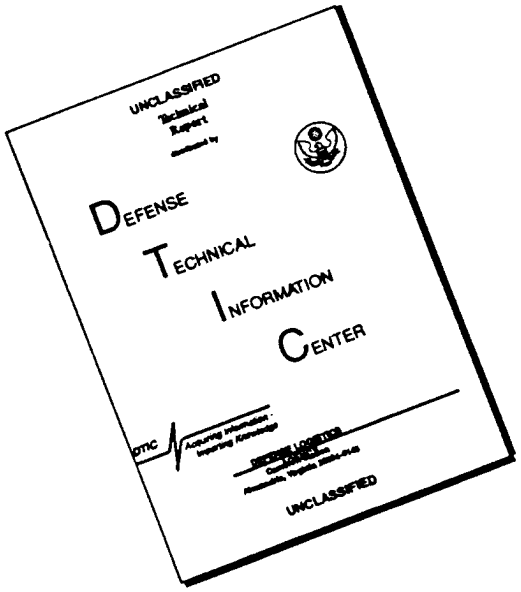

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NEW RADIOACTIVE ISOTOPES OF IRIDIUM

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March 3, 1950

Abstract

Four new isotopes of iridium have been prepared by bombarding isotope-enriched rhenium as well as natural rhenium with alpha-particles, and osmium with deuterons. Three of them have been identified as follows:

Isotope	Half-life	Type of Radiation	Energy of Radiation (Mev) Particle	γ-rays	Produced by
Ir^{187}	11.8h	$K\beta^+e^-\gamma$	β^+ 2.2 e^- 0.28, 1.2	L, K x-rays 1.3	Re(α,2n) Re^{185}(α,2n) Os(d,3n)
Ir^{188}	41.5h	$K\beta^+e^-\gamma$	β^+ 2.0 e^- 0.16, 0.85	L, K x-rays 1.8	Re(α,n) (α,3n) Re^{187}(α,3n) Os(d,2n), (d,3n)
Ir^{190}	3.2h	$K(?)\beta^+e^-\gamma$	β^+ 1.7 e^- 0.2, 0.8	--	Re(α,n) Re^{187}(α,n) Os(d,n), (d,2n)

The 3.2h period is an isomer of the 12.6 d Ir^{190}.

Another weak activity, possibly Ir^{189}, of more than 100 days half-life has been observed.

Four daughter activities of iridium (9.5 m, 6h, 35h and ca. 50-day radio-osmium) have been found, and their possible genetic relations discussed.

A rhenium activity of ca. 1 hr half-life has been noticed in the Os + 19 Mev deuteron experiment.

I. Introduction

The previous work on this element, iridium, has resulted in the observation of a number of radioactive isotopes.(1) However, on the neutron deficient side of the stable isotopes only one period has been reported.(2) The isotope chart shows that the following mass numbers of Ir, 186, 187, 188, 189 and 190 can be produced by (α,n), (α,2n), and (α,3n) reactions on rhenium, which has two stable isotopes, Re^{185} and Re^{187}, of relative abundance 38.2% and 61.8% respectively. Using the 60-inch cyclotron at the Crocker Laboratory, this attractive field was investigated. Enriched rhenium isotopes and spongy osmium were also used in confirmatory work concerning the reactions and the mass assignments of the products.

(1) G. T. Seaborg and I. Perlman, Rev. Mod. Phys. 20, 585 (1948).

(2) L. J. Goodman and M. L. Pool, Phys. Rev. 70, 112 (1946); 71, 288 (1947).

Table I

Isotopic Compositions of Rhenium Samples

Isotope	Natural Rhenium	"Re 185"*	"Re 187"*
185	38.2	85.38	1.78
187	61.8	14.62	98.22

* Obtained from Carbide and Carbon Co., Chemistry Div., Oak Ridge, Tenn.

II. Experimental

Bombardments of rhenium with 38-Mev helium ions and of osmium with 19-Mev deuterons were made in the 60-inch cyclotron. Metallic rhenium powder (100 mg.) was mounted on a copper target plate and covered with 0.2 mil tantalum foil. In the case of osmium, samples of the spongy metal were bombarded on a water-cooled platinum interceptor, also using 0.2 mil Ta foil to protect the powder. Experiments with low energy α-particles were made by placing a suitable thickness of Ta foil over the target to act as an absorber. (Calculated from range-energy chart for α's drawn from the data of Aron, Hoffman and Williams).

After bombardment, the rhenium target was dissolved in dilute nitric acid, and the osmium in aqua regia, in an all-glass distilling flask. Chemical separations were made after the addition of proper inactive carriers. Osmium was separated by distillation of the volatile tetroxide followed by precipitation of the sulfide with sodium thiosulfate. The mother liquor was evaporated to dryness and then taken up with water. Iridium was reduced to the metal by formic acid in hot solution. After removal of these elements, rhenium was finally precipitated as the sulfide with sodium thiosulfate.

"End on" type argon-ethanol filled Geiger counters with approximately 3 mg/cm^2 mica windows were used throughout the experiment. Coincidence and geometrical corrections have been applied to all the counts. Variations in counter efficiency were checked by a UX_2 standard. A beta-ray spectrometer of low-resolving power was used to differentiate the positrons and the beta-particles.

Radiation characteristics were studied by using beryllium, aluminum and lead absorbers. Electron and soft electromagnetic radiations were distinguished by their differential absorption in aluminum and beryllium.[3] The average energy of L x-rays

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(3) G. Wilkinson, Phys. Rev. 75, 1019 (1949)

in this region is of the order of 9 Kev with an absorption half-thickness in beryllium of 700 mg/cm^2. For the lead absorption, lead screens were used with beryllium absorbers, placed below and above the lead, of sufficient thickness to remove all the electrons from the sample and the secondary electrons emitted from the lead, respectively.

The ratios of electrons and the electromagnetic radiations were determined with due corrections for counter window and air gap absorptions of electrons as well as for counting efficiencies of quantum radiations. Thus, for the L x-rays a counting efficiency of 5% was assumed, for γ-rays from 20 Kev to less than 500 Kev, 0.5%, from 500 Kev to 1 Mev, 1%, etc. Cross sections were calculated for thin samples. The total beam current to the target was integrated by the cyclotron instruments. In these calculations the relative values should be more correct than the absolute values.

III. Results

Four half-lives, $3.2 \pm .2$ hour, $11.8 \pm .3$ hour, $41.5 \pm .5$ hour and $12.6 \pm .3$ day were observed in the iridium fraction separated from rhenium bombarded with 30-Mev helium ions. The first three isotopes emitted positive electrons (Fig. 1). A 19-Mev deuteron bombardment on osmium gave the above mentioned activities and the well known 75-day Ir^{192} as the major product.

One additional weak period of more than 100 days was observed in the iridium fraction from rhenium bombarded with approximately 40-Mev α-particles in the 184-inch cyclotron, but it was not studied in detail.

The relative yields of the activities obtained by varying the energy of the impinging alpha-particles are shown in Table II and Fig. 2.

Table II

Relative Yields of the Radioiridium at Various α-energies

Sample	Impinging α-energy	3.2 hr.	11.8 hr.	41.5 hr.	12.6 d.
Natural	21 Mev	14.8	5.9	36.2	43.0
Rhenium	25	9.0	27.0	22.8	41.3
	~ 30	11.0	27.9	25.2	35.9
	38	3.0	38.2	42.5	16.2
	~ 40	2.5	41.5	43.7	12.2
Enriched	22 Mev	9.8	3.1	25.8	61.2
"Re 187"	32	2.2	-	78.7	19.0
"Re 185"	32 Mev	-	84.4	13.7	1.8

11.8 h Ir^{187}

In Fig. 2 it is seen that the yield of this activity increases with increasing alpha energy in the bombardment of natural rhenium. From this and the results of the experiments with enriched rhenium isotopes, this period was assigned to Ir^{187} with confidence. The increasing trend of the yield curve might be explained by assuming the possible contribution of an (α,4n) reaction in the 38 to 40 Mev alpha range, where it is usually acknowledged that the (α,3n) reaction should play the principal role.

From gross and differential decay its half-life was found to be 11.8 ± .3 hr. Magnetic counter readings both from Re + α and Os + d sources indicated the presence of positrons (Fig. 1).

A satisfactory characterization of the radiations by absorption measurements

was not obtained, since its measured activity was too close to that of the 41.5 h period. However, a group of harder electrons with maximum energy of 1.2 Mev and a softer group of 0.28 Mev were found both from absorption measurements and beta-ray spectrometer readings of the iridium fraction isolated from the bombardments of the enriched Re^{185} target (Figs. 3 and 4(I)). The beta-ray spectrometer record was taken at an early stage when this activity was present predominantly. It shows that the positrons (curve A) had a maximum energy of 2.2 Mev and a mean energy of approximately 0.7 Mev. Since the β^+/electron capture branching ratio is small their maximum energy was not determined by aluminum absorption. Any such contribution from β^+ would be buried in the strong electromagnetic background, which showed components with half-thicknesses in lead of 150 mg/cm^2, corresponding to 63 Kev, and 12.5 g/cm^2, approximately 1.3 Mev. The former corresponds well with the osmium K x-rays. The L x-rays of half-thickness 24 mg/cm^2 aluminum, corresponded to~9 Kev.

An approximate ratio of positive and negative electrons and electromagnetic radiations was obtained from absorption measurements, the usual corrections for counter window, counting efficiencies, etc. being considered.

0.28 Mev e_1	1.2 Mev e_2	2.2 Mev β^+	L x-rays	K x-rays	1.3 Mev γ =
0.22	0.025	0.002	0.62	1	0.75

The ratio of L x-radiation to K x-rays is comparatively higher than those of other periods studied; this, and also the high yield of electrons seemed to suggest the possibility of some L electron captures, and of course, the possibility of a γ-ray of this energy accounting for the excess of L x-rays can not be excluded. Assuming that one K x-ray represents one disintegration by orbital electron capture, about 0.2% of the disintegrations of this activity occurs by positron emission.

41.5 h Ir^{188}

This isotope was both produced from α-bombardment on rhenium and deuteron bombardment on osmium. A study of its yield from natural rhenium targets justifies

postulating its formation by an (α,n) reaction on Re^{185} and an (α,3n) reaction on Re^{187}.

Gross and differential decay measurements give 41.5 hr as its half-life. The aluminum absorption curve (Fig. 5) which has been corrected for the contributions of the 12.6 d Ir^{190} and the 41.5 h L x-rays, 9 Kev, shows at least three components. A hard one has an end point at 300 mg/cm^2 corresponding to a maximum energy of 0.85 Mev according to Feather's formula, a soft one has a range of 25 mg/cm^2 or an energy of 0.16 Mev, and a still harder particle of an approximate range of 900 mg/cm^2, approximately 2 Mev.

Beta-ray spectrometric examination showed also the existence of positions. The momentum distribution curve (Fig. 4(II)) shows the end point corresponding to 2 Mev and a mean energy of approximately 0.5 Mev. Curve B of Fig 4(II) stands for the negative electron distribution, with end point of the harder group corresponding to a maximum energy of 0.85 Mev and an average of 0.3 Mev, and the lower energy peak corresponded to 0.16 Mev for its softer group. All check very well with the aluminum absorption measurements. The soft part probably represents a single conversion electron, while the broader one may be a mixture of several conversion electrons.

In Fig. 5 is also shown the lead absorption of the electromagnetic radiations. The soft component has a half-thickness of 145 mg/cm^2 corresponding to 62 Kev, which is quite an acceptable value for osmium K x-rays. The gamma-ray has a half-thickness of 15 g/cm^2 corresponding to 1.8 Mev.

The ratios of the various radiations were obtained from aluminum and lead absorption measurements as follows:

0.16 Mev e_1	0.85 Mev e_2	2 Mev β^+	L x-rays	K x-rays	1.8 Mev γ
0.08	0.007	0.003	0.21	1	0.55

Assuming that some of the K x-rays arise from production of the conversion electrons, then from the above ratio, approximately 90% of the K x-rays must arise from orbital electron capture and hence it is assumed that 0.90 K x-ray represents one disintegration. The branching ratio for the positron disintegration is somewhere around 0.3%.

3.2 h Ir^{190}

In the course of this work the 3.2 ± .2 hr positron emitter was always found in small quantities both in the Re + α and Os + d reactions. The possibility of its being an impurity received first attention. Spectroscopic analysis of one of the natural rhenium samples showed only a trace of silicon present (0.01-0.1%), and any other impurities would not exceed this amount. Chemical separation proved it was an iridium activity, and in several later experiments include those with enriched Re^{187}, it was present in amount greater than 10% of the total iridium activity.

From the results of the magnetic counter measurements (Fig. 4(IV)), the positive electron has a maximum energy of 1.7 Mev and a mean value of approximately 0.6 Mev. The spectrum of the negative electron is complex and consists of at least two groups. A line of conversion electron appeared at $H\rho$ = 1570 Gauss-cm corresponding to 0.2 Mev. The harder group has a maximum energy of 0.8 Mev and a mean value of 0.25 Mev. On account of the relatively strong intensities of both the 11.8 h and 41.5 h isotopes which occurred with this activity, the aluminum absorption curve (Fig. 6) is not resolved, but suggests that the mixed positive and negative electrons have a maximum range of energy of 1.8 Mev and a softer group of approximately 0.2 Mev. Even more trouble was encountered with the γ's.

Of these three positron emitting activities of iridium, this one must have the largest β^+ to electron capture branching ratio.

12.6 d Ir^{190}

Goodman and Pool[2] have already assigned to Ir^{190} a 10.7 d activity obtained from deuteron bombardment of Os and from an (n,2n) reaction on Ir. In this experiment it was also produced by an (α,n) reaction on Re. Enriched Re^{187} produced more than 10 times the amount of this activity as the enriched Re^{185} when both were subjected to 32-Mev α-bombardment. The assignment of this period to Ir^{190} is therefore well confirmed. The best value for its half-life, followed through nine half-lives, is 12.6 ± .3 days.

The aluminum absorption curve in Fig. 7, shows for the soft and hard groups of electrons, after correction for L x-rays, energies of 0.17 Mev and 0.5 Mev respectively. The absorption curve obtained from the Os + d experiment, after deducting the contributions from the 75d Ir, revealed the same characteristics. This is a little different from what Goodman and Pool have observed. The γ-rays of half-thicknesses of 400 mg/cm^2 lead, corresponding to 0.17 Mev, and of 5.2 g/cm^2 lead, corresponding to 0.55 Mev, were clearly disclosed by lead absorbers (Fig. 7). The K x-rays were not definitely observed, the radiation resolved from soft and hard γ-quanta showing a half-thickness of only 80 mg/cm^2 lead. A stronger sample would probably give better results.

However, an estimation of the approximate ratio of radiations, with proper allowances for various assumptions was made as follows:

0.17 Mev e_1	0.5 Mev e_2	L x-rays	K x-rays	0.17 Mev γ_1	0.55 Mev γ_2
= 0.07	0.04	0.15	1	0.45	0.42

Assuming that K x-radiation also arises from the process of conversion, then about 0.85 K x-ray will represent one disintegration by orbital electron capture.

Osmium Daughters

Four low activities of osmium, 9.5 m, 6 h, approximately 35 h and approximately 50 d, were obtained from "milking" experiments on mixed artificial radioactive iridium. They were also observed in the osmium fraction separated directly from rhenium targets. In some instances the well-known 95-day osmium was found to be present in the direct separations.

The 9.5 m period was present in every direct separation, but appeared only in the early milkings. In one sample from an Os + deuteron bombardment, the milking process was carried out from time to time covering a period of 35 days. The 9.5 m activity disappeared after one day, the 35 h disappeared after a week, the 50 d after 17 days, while the 6 h period lasted throughout. Based on the interval of separation and relative number of atoms of growth and decay, the 9.5 m osmium was found to be

the daughter of 3.2 h Ir^{190}. The 35h Os and 6 h Os are possibly related to the 11.8 h Ir^{187} and the 12.6 d Ir^{190} respectively. The 50-day osmium was very weak, but it was definitely distinguishable from the 95-day Os. In the first place, the Ir activities used for milking were reduced after the mother liquor had been evaporated to dryness, expelling osmium activity which might remain in the mother liquor. Secondly, the gross decay curve of one of the direct separations has revealed the co-existence of the approximately 50 d and the 95 d periods.

The radiations of these activities have not been successfully studied. For the 9.5 m period, the aluminum absorption curve give a maximum energy of 0.5 Mev, indicating the mixed energy of soft electromagnetic radiation and electrons (factor of decay being corrected) (Fig. 8). An aluminum absorption curve for the 6 h Os is also shown in Fig. 8.

No positrons were detected from one comparatively strong sample of these osmium activities.

Other Activities

(1) 75-day Ir^{192}

In the bombardment of osmium with deuterons there was a very good yield of the well known Ir^{192}. The best value for its half-life is 74.7 days. The electron range in aluminum has a maximum value of 0.68 Mev according to Feather's method, and the gamma energy from lead absorption is 0.42 Mev.

(2) 95-day Os^{185}

The irradiation of rhenium with deuterons led to the production of the 95-day Os. It was also observed in minute quantities in the rhenium + α, and osmium + d bombardments. Its radiation characteristics were found to agree with those given by Katzin and Pobereskin.[4]

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(4) L. I. Katzin and M. Pobereskin, Phys. Rev. 74, 264 (1948).

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(3) 16-day Os^{191}; 30.6-hour Os^{193}

These isotopes were observed as the products of (d,p) reactions on osmium. The best half-life for

Os^{191}, after subtracting the contributions from the long-lived 95-day isotope is 16.0 ± .3 days, and that for Os^{193} is 30.6 ± .4 hours. The absorption curve of the 16 d Os with correction for L x-rays, showed a weak conversion electron of 0.15 Mev in aluminum, and the gamma in lead corresponded to 0.14 Mev. These data are consistent with Katzin and Pobereskin's[4] and Saxon's[5] measurements.

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(5) D. Saxon, Phys. Rev. 74, 1264 (A) (1948).

The aluminum absorption curve of the 30.6 h β-emitter showed an end point of 440 mg/cm^2 corresponding to 1.15 Mev as was found by Mandeville et al.[6]

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(6) C. E. Mandeville, M. V. Scherb, and W. B. Keighton, Phys. Rev. 74, 888 (1948).

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(4) 90-hour Re^{186}; 17-hour Re^{188}

These well established isotopes were formed by (d,p) reactions on rhenium in proportion very close to the natural abundance ratio of Re^{185} and Re^{187}. The β-particles of Re^{186} showed a range in aluminum corresponding to 0.96 Mev, and that of Re^{188} corresponded to 2.2 Mev.

They were also observed in the Re fraction from Re + α bombardment, especially when the α-energy was below the threshold of (α,n) reaction. This is another instance of the large neutron cross section of rhenium.[7]

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(7) J. M. Cork, R. G. Shreffler, and C. M. Fowler, Phys. Rev. 74, 1657 (1948).

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(5) 1-hour Re

In the experiment with Os + d (19 Mev), an activity of approximately 1 hour half-life was noticed in the rhenium fraction. If it is not due to an impurity, it may probably be the product of a (d,α) reaction.

IV Discussion

From the curves of relative yields shown in Fig. 2, it seems quite probable to assign the 41.5 h period to Ir^{188}, the 11.8 h period either to Ir^{187} or to Ir^{189}, and the 3.2 h period as an isomer of the 12.6 d Ir^{190}.

The assignment of the 41.5 h to Ir^{188} was rather obvious considering its yield from natural rhenium which has two stable isotopes, 185 and 187, of relative abundance 38.2% and 61.8%, respectively. The predominance at lower energy α-bombardments of the (α,n) reaction of the 185 isotope, and at higher energies of the (α,3n) reaction on the 187 isotope affords a ready explanation of the shape of the yield curve. Further evidence was obtained from experiment with enriched rhenium isotopes. In Table II, it is seen that a very much greater yield of this activity was obtained from "Re 187", which was subjected under the same experimental condition as "Re 185" (both being kept side by side at the center of the 32-Mev α-beam). Since an (α,3n) reaction should predominate over (α,n) at 32 Mev, the above assignment is confirmed.

The allocation of the 11.8h activity to Ir^{187} was strongly suggested by the joint bombardment of the enriched rhenium isotopes. With 32 Mev α's the "Re 185", which has been enriched to 85.38% Re^{185} (Table I), gave a corresponding ratio of yield of the 11.8 h Ir activity (84.4%), and none of this activity was obtained from the "Re 187" (98.22% Re^{187}) target. Additional support was obtained from the 19-Mev deuteron bombardment on osmium; wherein (d,n),(d,2n), and (d,3n) all were possible reactions. The relative yield of the 11.8 h Ir was about half as much as that of the 41.5 h Ir, which agreed with the ratio of the sum of the relative abundances of Os^{186} 1.59% + Os^{187} 1.64% + Os^{188} 13.3% (total 16.53% available for Ir^{187}) and that of Os^{187} 1.64% + Os^{188} 13.3% + Os^{189} 16.1% (31.04% available for Ir^{188}).

The 12.6 d period has been reported (as 10.7d) and assigned to Ir^{190} by Goodman and Pool.[2] The present work substantiates their conclusion. The assignment

of the 3.2 h positron emitter as an isomer of Ir^{190} rather than to Ir^{188} was supported by the ratio of yield both from natural and enriched rhenium targets. The yield of the 3.2 activity kept reasonable pace with that of the 12.6 d, but it was quite different from that of the 41.5 h period.

The cross sections for the production of the radioactive isotopes are given in Table III. In spite of the uncertainties involved in the absolute cross

Table III

Cross Sections in Barns for α-particle Reactions on Enriched Re

Sample	α-energy	11.8 Ir^{187}	41.5 h Ir^{188}	3.2 h Ir^{190}	12.6 d Ir^{190}
"Re 187"	22 Mev	0.009	0.13	0.01	0.24
"Re 187"	32 "	-	0.81	0.006	0.15
"Re 185"	32 "	1.2	0.21	-	0.022

section calculations, the reliability of their relative values is worthy of mention. From Table I we see that the enriched "Re 187" sample contains 98.22% Re^{187} isotope and the "Re 185" contains 14.62% Re^{187}. The rate of formation of the 12.6 d activity from the two enriched rhenium samples, $\sigma(Re^{187})/\sigma(Re^{185})$ = 0.15/0.022 = 6.8, corresponds very well to the ratio of the Re^{187} percentage compositions, 98.22/14.62 = 6.7. Meanwhile by considering the relative σ's of the production of the 3.2 h and 12.6 d activities from 22-Mev α and 32-Mev α-bombardments, the ratio of the two members of Ir^{190} isomer may be estimated as about 1:20.

We should expect Ir^{186} and Ir^{189} to appear in this experiment as results of (α,2n) and (α,3n) reactions on Re. But since no other activity was apparent from 21-Mev α up to 38-Mev α-bombardments (from 1 μAH to 15 μAH), we must presume that their half-lives are long or fairly short. In the latter case any radio-

activity with a half-life less than 5 min. would have been difficult to observe, since there was necessarily a delay of 3/4 hour to one hour between the end of bombardment and the first count. Whether the above-mentioned weak period of more than 100 days can be assigned to either of these, will require further study; but it could feasibly be Ir^{189}, which can be expected to have a comparatively long half-life.

The relative yields of osmium activities, found growing in the iridium fraction, and also found in the osmium fraction from Re + α bombardment, were very small. They were probably formed as daughters of the Ir activities. The initial samples were all very weak, one could only relate the 9.5 m Os to the 3.2 h Ir with certainty. The results of milking experiments suggested, in addition, a possible relationship between the 6 h Os and the 12.6 d Ir, and between the 35 h Os and the 11.8 h Ir. Since osmium isotopes of masses 186 through 190 exist in nature, any radioactivity due to them must be associated with the existence of excited states of the stable isotopes.

V Acknowledgments

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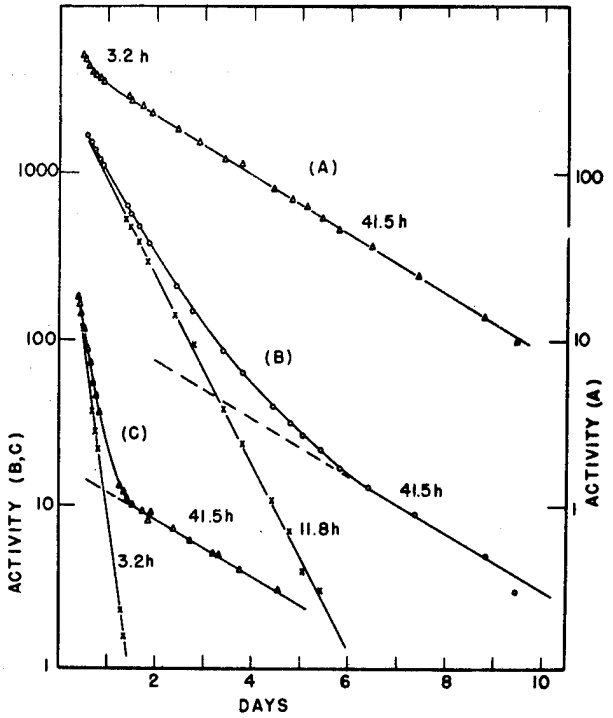

Fig. 1—Decay of Positrons of Radioactive Iridium. (A) 41.5 h Ir^{188} from enriched "Re 187" + 32-Mev α-particles. (B) 11.8 h Ir^{187} and 41.5 h Ir^{188} from "Re 185" + 32-Mev α. (C) 3.2 h Ir^{190} and 41.5 h Ir^{188} from "Re 187" + 22-Mev α.

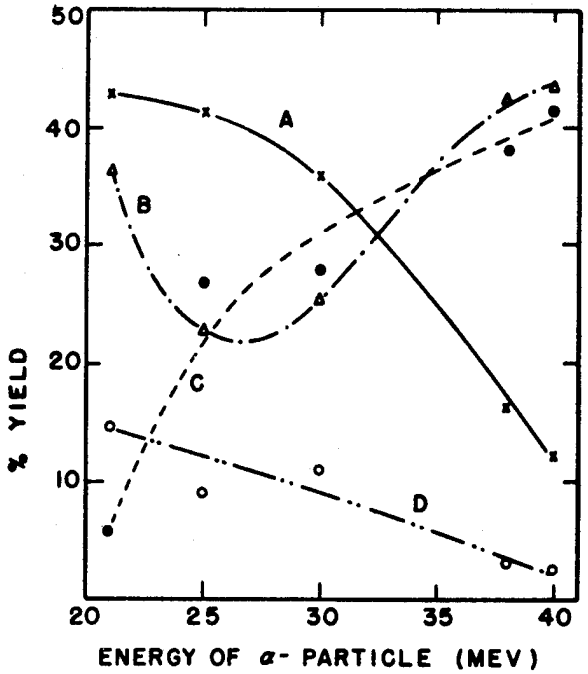

Fig. 2—Relative Yields of the Radioactive Iridium from Re + α Particles. (A) 12.6 d Ir^{190}. (B) 41.5 h Ir^{188}. (C) 11.8 h Ir^{187}. (D) 3.2 h Ir^{190}.

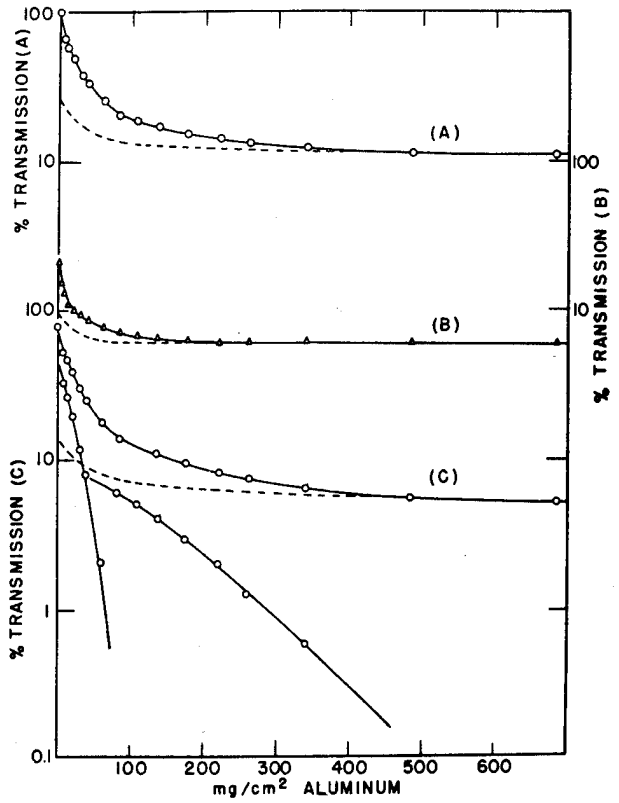

Fig. 3 — Aluminum Absorption of 11.8 h Ir^{187} and 41.5 h Ir^{188} from "Re 185" + α. (A) Measured curve for mixed activities. (B) Contribution of the 41.5 h activity at the time when (A) was taken. (C) Resolved absorption of 11.8 h Ir^{187}.

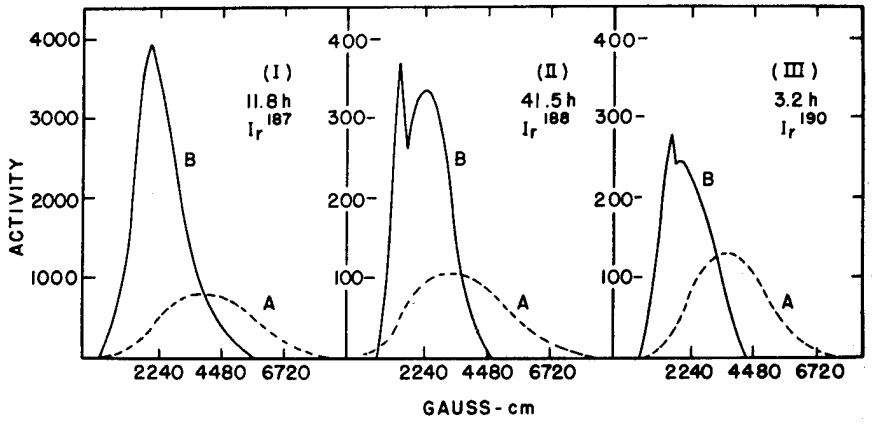

Fig. 4 — The Beta-spectra of the Iridium Isotopes. (A) Positrons; (B) Electrons. (I) 11.8 h Ir^{187}; (II) 41.5 h Ir^{188}; (III) 3.2 h Ir^{190}.

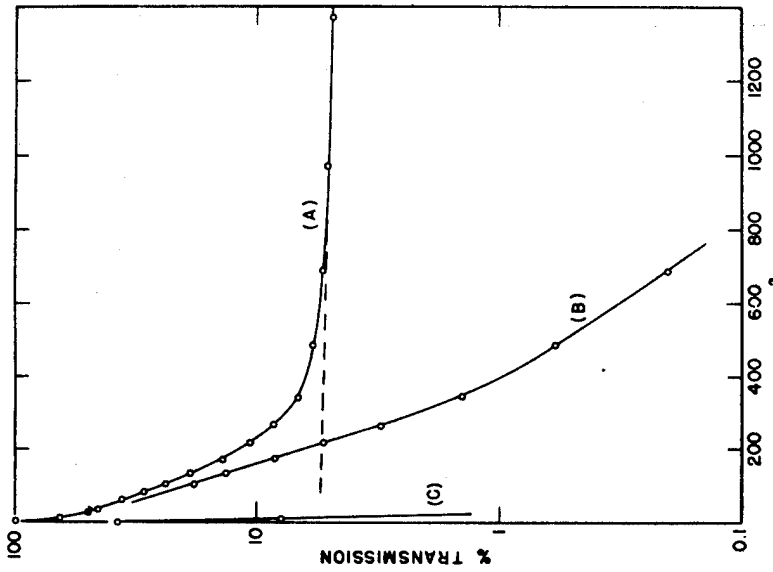

Fig. 6 — Aluminum Absorption of 3.2 h Ir^{190} and 41.5 h Ir^{188}. (A) Measured at 2 hours after bombardment. (B) Positrons and hard electrons. (C) Soft electrons.

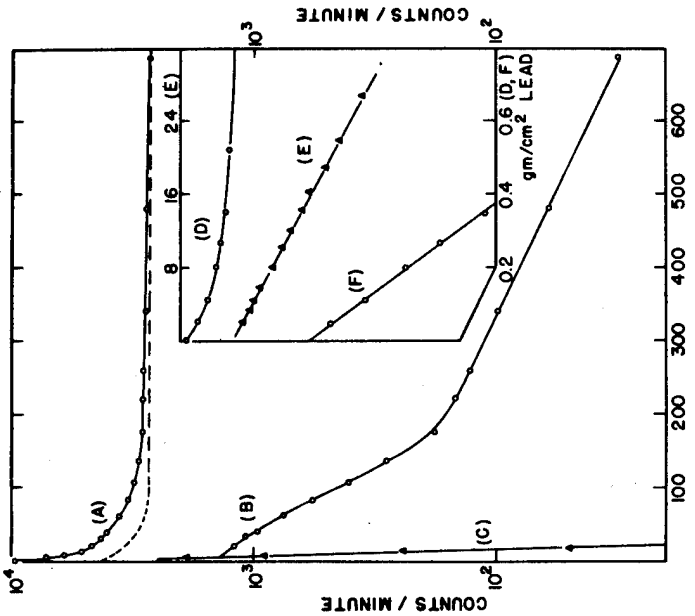

Fig. 5 — Absorption Curves for 41.5 h Ir^{188}. (A) Measured curve in aluminum, with L x-ray, K x-ray, and γ-ray background. (B) Positrons and hard electrons. (C) Soft electrons. (D) and (E) The first and second halves of the measured curve in lead, drawn in different scale, showing hard γ-ray of 15 gm/cm^2 half-thickness. (F) K x-ray, half-thickness 145 mg/cm^2.

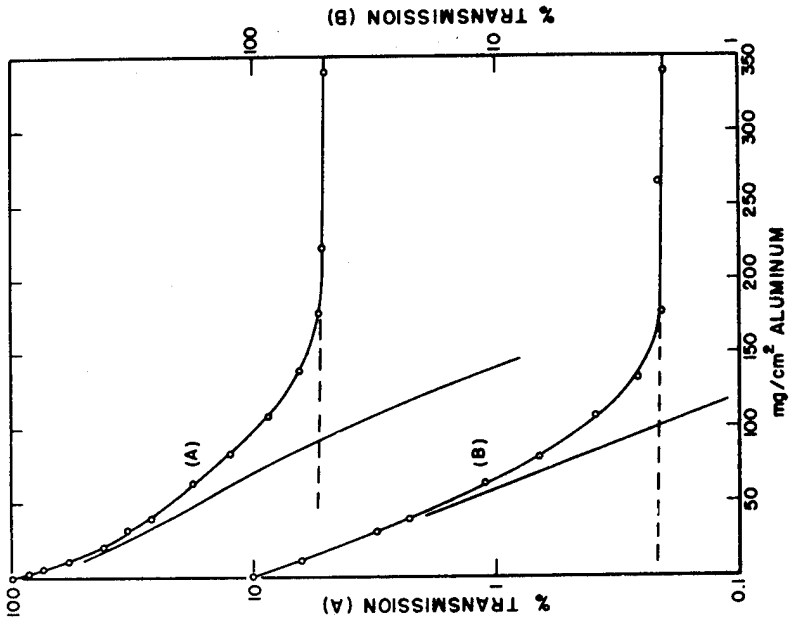

Fig. 8—Aluminum Absorption Curves for the 9.5 m Os (A), and the 6 h Os (B).

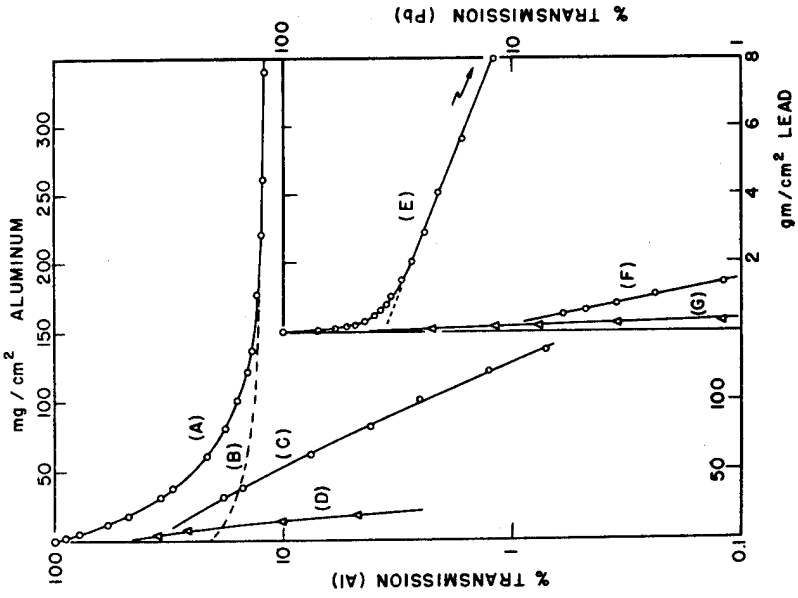

Fig. 7—Absorption Curves of 12.6 d Ir^{190}. (A) Aluminum absorption curve. (B) L x-ray. (C) Hard electrons. (D) Soft electrons. (E) Lead absorption curve and the hard γ-ray. (F) Soft γ-ray. (G) K x-ray.

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